

ently less precise, sampling has less stringent timing requirements. Clock jitter, for example, impairs performance of a system with transistor-based circuits, more so that for systems with resistors.

**[0138]** Reference is now made to FIG. 20, which is a simplified flowchart of a method for PD sampling, in accordance with an embodiment of the present invention. The method shown in FIG. 20 relates to the transistor-based circuit of FIG. 18B, used to sample PDs.

**[0139]** At step 1000 all transistors, T1, T2 and T3, are turned off. At step 1005 a PD is selected by turning on transistor T2. At step 1010 the S/H circuit is opened, and transistor T1 is turned on. This causes capacitor C and the capacitor inside the S/H circuit to discharge. If the S/H circuit is not discharged, then residuals from previous measurements may arise. At step 1015 the S/H circuit is closed, for holding. At step 1020 transistor T1 is turned off, in order to begin current integration. At step 1025 the method waits a designated amount of time, such as 10  $\mu$ s. At step 1030 the S/H circuit is opened. At step 1035 the method waits for at least the minimum amount of time required by the S/H circuit; e.g., 1  $\mu$ s. At step 1040 the S/H circuit is closed, and the analog to digital conversion begins.

**[0140]** At step 1045 transistor T1 is turned on, in order to discharge capacitor C. At step 1050 the method waits 1  $\mu$ s for the capacitor for discharge. At step 1055 the LED is turned on, by turning on transistor T3.

**[0141]** At step 1060 transistor T1 is turned off, to begin a new integration/measurement. At step 1065 the method waits for a designated amount of time, generally the same amount of time as in step 1025. Step 1065 is done for performance. At step 1070 the S/H circuit is opened. The conversion from step 1040 must be ready and stored. At step 1075 the method waits for at least the minimum amount of time required by the S/H circuit; e.g., 1  $\mu$ s. At step 1080 the S/H circuit is closed, and the analog to digital conversion begins. At step 1085 the LED is turned off, by turning off transistor T3. At step 1090 transistor T1 is turned on, in order to discharge capacitor C. Finally, at step 1095 the method waits 1  $\mu$ s for the capacitor for discharge.

**[0142]** In accordance with an embodiment of the present invention, steps 1000-1095 of FIG. 20 are repeated several times, e.g., 5-20 times, in order to obtain a plurality of measurements when the LED is on, and a plurality of measurements when the LED is off. The background ambient light is then measured by accumulating values when the LED is on and subtracting values when the LED is off.

**[0143]** In this regard, reference is now made to FIG. 21, which illustrates measuring ambient light by summing pulses when an LED is on and subtracting pulses when the LED is off, in accordance with an embodiment of the present invention. In terms of samples A thru J shown in FIG. 21, the accumulated signal is B-A+D-C+F-E+H-G+J-I. A signal to noise ratio is given by

$$\frac{S}{N} = \frac{\sum \text{signals}}{\sqrt{\sum \text{noise}^2}}$$

The signal is accumulated based on a voltage metric that is a square of power. The noise is accumulated by a power metric

that is the square root of the voltage. In case the signal is significantly less than the background light, then DC blocking is used.

**[0144]** It will be appreciated by those skilled in the art that the method of FIG. 20 affords many advantages, including inter alia:

**[0145]** quick switch between measurements of different PDs, and short settle time;

**[0146]** substantially equal amplification of background (AC) and light pulses (DC); and

**[0147]** ability to measure pulse trains.

**[0148]** In an alternative embodiment of the present invention, integration and analog to digital conversion are performed in sequence. This alternative embodiment has the advantage that the capacitor in the S/H circuit is discharged prior to each current integration, providing for more accurate measurement. Thus if this alternative embodiment is implemented using an ASIC, then the integrator and the S/H may be in the same function block. However, if analog to digital conversion of a first signal is to be done simultaneous with integration of a second signal, then the integrator and the S/H should be in separate function blocks.

**[0149]** Reference is now made to FIG. 22, which is a simplified flowchart of an alternative method for PD sampling, in accordance with an embodiment of the present invention. The method shown in FIG. 22 relates to the transistor-based circuit of FIG. 18B, used to sample PDs.

**[0150]** At step 1100 all transistors, T1, T2 and T3, are turned off. At step 1105 a PD is selected by turning on transistor T2. At step 1110 the S/H circuit is opened and transistor T1 is turned on. This serves to discharge capacitor C and the capacitor inside the S/H circuit. If the S/H circuit is not discharged, then residuals from previous measurements may arise. At step 1115 the method waits 1  $\mu$ s for the capacitor to discharge. At step 1120 transistor T1 is turned off, to begin current integration. At step 1125 the method waits a designated amount of time; e.g., 10  $\mu$ s. At step 1130 the S/H circuit is closed, and the analog to digital conversion begins. At step 1135 the method waits for the conversion from step 1130 to complete.

**[0151]** At step 1140 transistor T1 is turned on, to discharge capacitor C, and the S/H circuit is opened. At step 1145 the method waits 1  $\mu$ s for the capacitor to discharge. At step 1150 the LED is turned on, by turning on transistor T3. At step 1155 transistor T1 is turned off, to begin a new integration/measurement. At step 1160 the method waits a designated amount of time, generally the same amount of time as from step 1125. Step 1160 is done for performance.

**[0152]** At step 1165 the S/H circuit is closed, and the analog to digital conversion begins. At step 1170 the LED is turned off, by turning off transistor T3. At step 1175 the method waits for the conversion to complete.

**[0153]** As with the method of FIG. 20, steps 1105-1175 of FIG. 22 are repeated for a plurality of pulses. Values when the LED is on are accumulated, and values when the LED is off are subtracted, in order to measure the ambient light.

**[0154]** viii. PD Signal Filter and Amplifier 175

**[0155]** Discussion now turns to the type of signal filter and amplifier circuit used, if any. FIG. 23A is a circuit diagram of signal filter and amplifier 175 used for PDs arranged along one edge of touch screen 100, in accordance with an embodiment of the present invention. The input to signal filter and amplifier 175, denoted PD\_COL, is the output current from a selected column PD. The output current of signal filter and